Structure of nuclei in the mass 250 region

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The nuclear structure of superheavy elements plays a very important role in the understanding and prediction of their nuclear properties. However, only few atoms of these nuclides can be produced because of the extremely low production cross sections. Thus, their structure must be deduced from systematics, using the information obtained on the structure of lower-mass nuclei. It is therefore essential to fully characterize the single-particle orbitals in nuclei that are available in sufficient quantities for such studies. The largest amount of the heaviest isotopes can be produced in the High Flux Isotope Reactor (HFIR) at Oak Ridge National Laboratory. This year we obtained extremely pure samples of ^{255}Fm, ^{253}Es and ^{251}Cf and studied their decay properties.

Extensive measurements of α-particle, conversion electron and γ-ray spectra have been performed with high-resolution semiconductor detectors. Alpha-particle spectra were measured by 25 mm^2 Passivated, Implanted, Planar Silicon (PIPS) detectors with resolutions (FWHM) of 9.2 keV. The α-particle energies directly provided the level energies in the daughter ^{247}Cm. More precise level energies were determined from the γ-ray spectra measured with a Low Energy Photon Spectrometer (LEPS). Conversion electron spectra measured with a 6-mm x 6-mm PIN diode of 0.3 mm thickness provided the transition multipolarities. Half-lives of the 227.4- and 404.9-keV levels were measured by the alpha-gamma delayed coincidence technique. Gamma-ray spectra were also measured in prompt and delayed coincidence with α particles. From the results of these measurements, the level scheme shown in Fig. 1, has been constructed [1] and spins, parities and Nilsson state assignments have been deduced. We have established the following single-particle states: 9/2$^-$[734], 0 keV; 5/2$^+$[622], 227.4 keV; 7/2$^+$[624], 285.1 keV; 1/2$^+$[620], 404.9 keV; 1/2$^+$[631], 518 keV. The experimental E2 transition rate between the 1/2$^+$[620] and 5/2$^+$[622] state was found to be ~100 times faster than the rate calculated with single-particle wavefunctions [2] and pair occupation probabilities [3]. The E2 matrix element is extremely sensitive to the pairing term because the 1/2$^+$[620] orbital is a particle state and the 5/2$^+$[622] orbital is a hole state. Thus the observed discrepancy could be either due to the incorrect pairing term and/or due to the admixture of the 1/2$^+$[620] wavefunction in the 5/2$^+$[622] state. Also, the E3 transition rate was measured between the 5/2$^+$[622] and 9/2$^-$[734] levels to be 5 Weisskopf units (W.u). This clearly demonstrates octupole mixing in the 5/2$^+$[622] level. Similar octupole mixing was observed in the 5/2$^+$[622] level in the isotone ^{249}Cf [4].

The decay of ^{255}Fm ($t_{1/2}$=20.1 h) was studied in 1998 and 2000 to investigate the level structure of ^{251}Cf, and the results from the 1998 study, which included gamma-gamma coincidence measurements with Gammasphere, were published [5] in 2000. In that study we were able to establish the assignment of the 1/2$^-$[750] Nilsson orbital to the 632-keV level. In addition, a K^p=3/2$^-$ and a 7/2$^+$ bands were identified at 982 and 1078 keV, respectively. The former was interpreted as the 2$^-$ octupole band coupled to the 7/2$^+$[613] orbital and the latter was interpreted as the β band coupled to the 7/2$^+$[613] configuration. We have measured the γ-singles spectra with a new source this year, which had less Es and other contaminants than previous samples. Also, gamma-gamma coincidence measurements were performed with Gammasphere. The results of these measurements confirm our earlier published results.

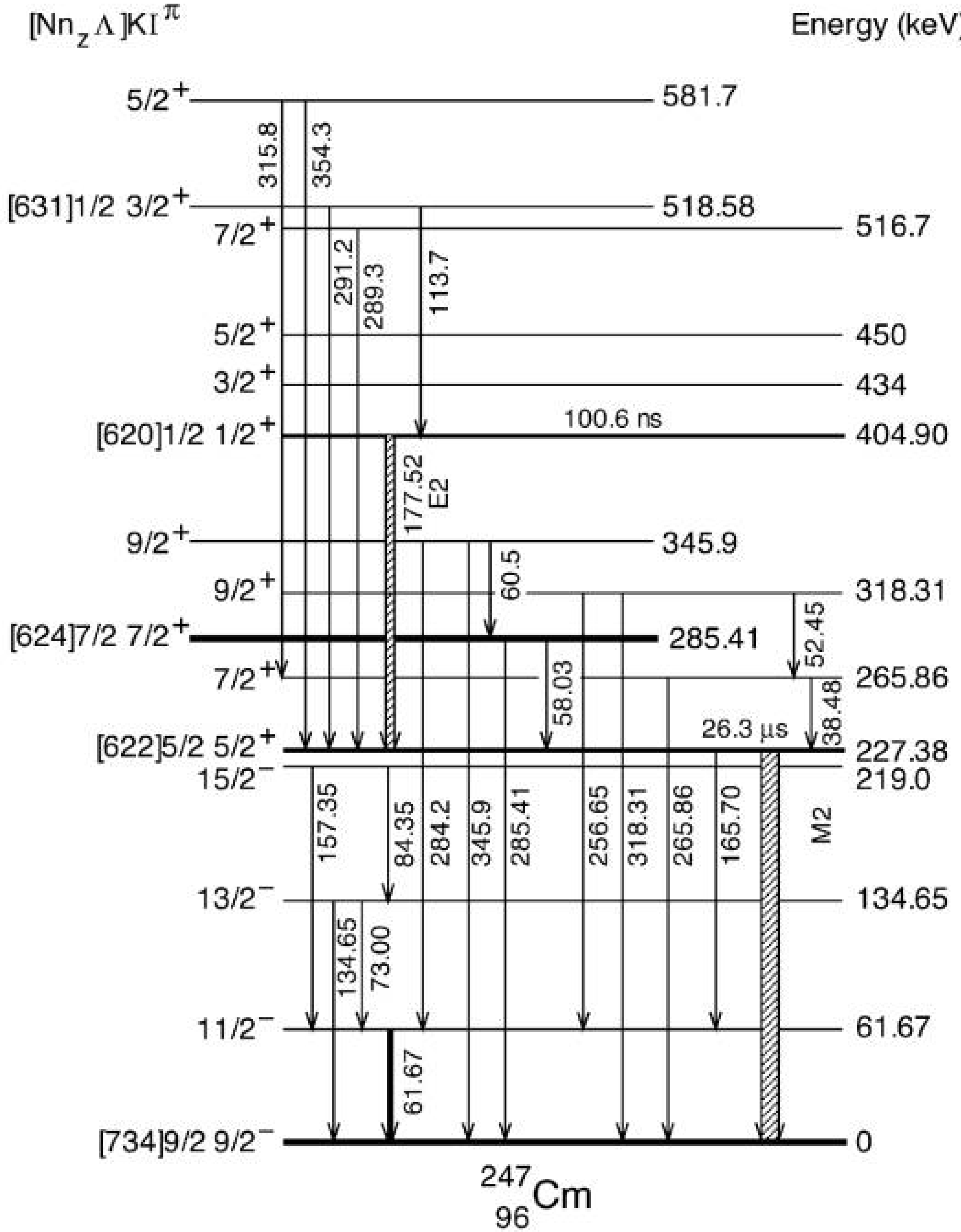

Figure 1. Level scheme of ^{247}Cm deduced from the study of ^{251}Cf alpha decay.

To investigate proton levels in ^{249}Bk we have used 1 mg ^{253}Es ($t_{1/2}$=20.47 d) for γ-singles and gamma-gamma coincidence measurements. This sample had an order of magnitude less ^{254}Es than any previous sample. This has allowed us to detect low-intensity γ rays. By following the decay of the γ-ray lines we have been able to assign gamma rays to ^{253}Es decay. Gamma-gamma coincidence measurements were performed with Gammasphere using 1 mg source. Data were accumulated for 5 days and are being analyzed. By combining the results of the present investigation with (α,t) and (^{3}He,d) reaction spectroscopy data [6], we hope to make a definite identification of the $1/2^-[521]$, $7/2^-[514]$ and $9/2^+[624]$ Nilsson orbitals in ^{249}Bk.

Calculations of single-particle spectra were made using a Woods-Saxon potential and pairing interaction [3] and these are in fair agreement with the observed level energies.

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